PCT

WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H04R 9/06

A1

(11) International Publication Number: WO 98/31188

(43) International Publication Date: 16 July 1998 (16.07.98)

(21) International Application Number: PCT/GB98/00014

(22) International Filing Date: 5 January 1998 (05.01.98)

(30) Priority Data:

9700363.6	9 January 1997 (09.01.97)	GB
9711593.5	6 June 1997 (06.06.97)	GB
9718730.6	4 September 1997 (04.09.97)	GB

(71) Applicant *(for all designated States except US)*: NEW TRANSDUCERS LIMITED [GB/GB]; Stonehill, Huntingdon, Cambrigeshire PE18 6ED (GB).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: AZIMA, Henry [CA/GB]; 3 Southacre Close, Chaucer Road, Cambridge CB2 2TT (GB). COLLOMS, Martin [GB/GB]; 22 Burgess Hill, London NW2 2DA (GB). ROBERTS, Martin [GB/GB]; 17 Home Farm Lane, Bury St. Edmunds, Suffolk IP3 2QJ (GB). BANK, Graham [GB/GB]; 1 Boartree Way, Huntingdon, Cambridgeshire PE18 6GL (GB). HARRIS, Neil [GB/GB]; 9 Davey Crescent, Great Shelford, Cambridge CB2 5JF (GB). DJAHANSOUZI, Bijan [GB/GB]; 101 Pier House, Cheyne Walk, London SW3 5HN (GB).

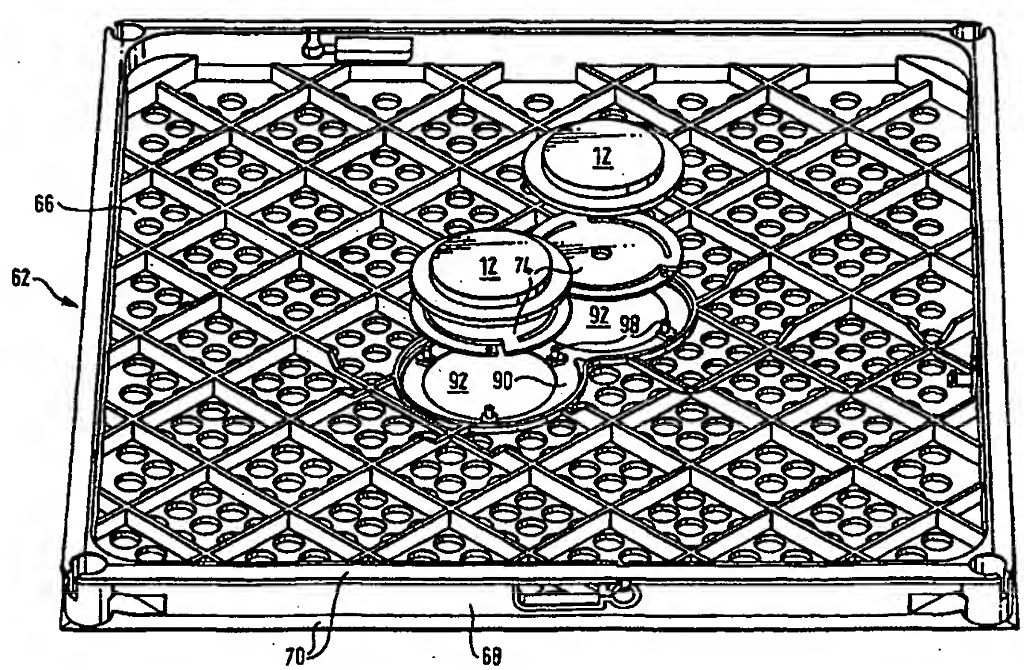
(74) Agent: MAGUIRE, BOSS; 5 Crown Street, St. Ives, Cambridgeshire PE17 4EB (GB).

(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published

With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: LOUDSPEAKERS



(57) Abstract

A loudspeaker drive unit comprising a resonant acoustic radiator, an exciter on the radiator to apply bending wave energy to the radiator to cause it to resonate, a support for the loudspeaker drive unit, and means resiliently coupling the exciter to the support.

TITLE: LOUDSPEAKERS

DESCRIPTION

The invention relates to loudspeakers of the kind in which an acoustic output is produced by applying bending waves to an acoustic radiator comprising a resonant member, e.g. a panel-form member, to cause it to resonate. Such loudspeakers are described in International patent application WO97/09842 of New Transducers Limited.

A vibration exciter for exciting such a resonant member needs a form of fixture onto the member to allow the best possible conversion of drive power into bending waves. An inertial reaction exciter applies a push/pull force to the member by reacting against the inertia of the driver mass and can be suitable.

Figures 1 and 2 show a known form of resonant panel-form loudspeaker (10) with one known kind of inertial

reaction vibration exciter or transducer (see Figure 11b of International application WO97/09842). (Figure 1 is schematic, whilst Figure 2 gives sectional detail of the exciter). Thus while Figure 1 shows parts of the exciter exploded apart in the interests of clarity, it will be clear from Figure 2 that in practice the parts of the exciter are closely arranged. The panel loudspeaker (10) comprises a vibration exciter (12) which is attached to one side of a stiff lightweight resonant panel (14). The exciter (12) includes coil winding (16) which is rigidly fixed, e.g. by means of an adhesive, on the outside of a coil former (18) to form a voice coil assembly (20) which is rigidly bonded to surface skin (22) of the panel (14), e.g. by means of an epoxy adhesive bond. Magnets (24) are enclosed by a pair of poles (26), one of which is disc-like and is disposed with its periphery close to the interior of each coil former (18), and the other of which has peripheral flange (28) arranged to surround the coil assembly (20). The magnet assembly (24,26) is secured to the surface of the panel (14) by means of a resilient suspension (30), e.g. of rubber, which is attached to the periphery of the flange (28) of the outer pole piece (26).

Figure 3 illustrates another known resonant panel-loudspeaker (32), (see Figures 7a,7b,7c of International application WO97/09842) comprising an exciter (12) which is attached to one side of resonant panel (14). The exciter (12) is similar to that described with reference to Figures 1 and 2, in that it has a voice coil assembly (20) and

magnet assembly (24,26). The voice coil assembly (20) is rigidly coupled to the panel (14) and the magnet assembly is secured to a frame (34) and resiliently rigidly secured to the panel (14) by means of a resilient suspension (30), e.g. of rubber. In practice, a resilient suspension is disposed around the periphery of the panel (14) and is coupled between the panel (14) and the frame (34), but in the present drawing this has been omitted for simplicity. By rigidly coupling a frame (34) to the magnet assembly (24,26), the advantages and disadvantage noted hereinbefore may result.

A resonant panel loudspeaker driven by an electro-dynamic exciter has a substantially flat sound pressure level response with frequency. There will, however, be a frequency below which the drive force to the panel will fall. It is possible to reduce this frequency and hence extend the bandwidth of the panel loudspeaker by increasing the inertia of the exciter magnet assembly. This may be achieved simply by adding more mass to the exciter magnet assembly or alternatively by coupling the exciter magnet assembly to a more massive body, for example to a support frame although both of these approaches can be disadvantageous in some respects. Thus an increase in the inertia of the exciter renders the exciter more sensitive to damaging shock during transportation or during handling, with the possibility even of damage to the resonant panel itself, while coupling the exciter rigidly to a support causes the exciter to cease to be truly inertial and

instead couples drive energy to the support.

It is among the objects of the present invention to provide a novel loudspeaker drive unit comprising a resonant acoustic radiator.

From one aspect the invention is a loudspeaker drive unit comprising a resonant acoustic radiator, an exciter on the radiator to apply bending wave energy to the radiator to cause it to resonate, a support for the loudspeaker drive unit, and means resiliently coupling the exciter to the support.

Coupling the exciter magnet assembly to a frame or the like support confers the advantage of increasing reliability and robustness while providing a resilient coupling can reduce the level of energy imparted to the support. The panel itself may be a fairly lightweight structure, whilst the exciter may be much heavier than the panel particularly in the case of an electrodynamic device. During rough handling or shipping it is possible for the exciter to move undesirably and even cause the pole pieces to contact with the windings of the voice coil, with obvious disastrous results. By coupling the exciter magnet to the frame it is possible to produce an assembly with much improved durability than one with the exciter "free"; as in Figures 1 and 2.

The resilient coupling of the exciter to the support may reduce the tendency for the support and drive means to move with the same velocities, and may even obviate coincidence of velocities altogether. Thus, in operation,

the panel may not be moving with either the same amplitude or even the same phase as the support. Furthermore, the choice of resilient coupling offers the designer freedom to "tune" resonant panel-form loudspeakers in a manner analogous to optimising multi-cavity and multi-vent loudspeaker systems.

For designs where the compliance is set to a low value, the exciter may be more rigidly held by the support frame and may result in a better resistance to mechanical shock together with a reduced roll off rate for the acoustic output at low frequencies applicable to some environments.

With median compliance values for the resilient element the higher frequency components of velocity present in the exciter are beneficially more weakly coupled to the support frame and this may reduce the stray acoustic output which the support frame may radiate.

With higher compliance for the resilient coupling component it may be beneficially tuned in association with the moving mass component of the exciter as is explained further below.

The support may also be resiliently coupled to the resonant member. The resilient coupling between the resonant member and the support may be spaced from contact between the resonant member and vibration exciter.

The vibration exciter may comprise an inertial vibration exciter. The inertial vibration exciter may comprise a magnet assembly and motor coil. The motor coil

may be rigidly mounted to the resonant member, and the magnet assembly may be resiliently mounted to the resonant member as well as to the support.

In another aspect the invention is a loudspeaker comprising a drive unit as described above.

In yet another aspect, the present invention provides a loudspeaker comprising a support and a vibration exciter supported thereby for producing an acoustic output, characterised in that a resilient member is coupled between the vibration exciter and the support. The loudspeaker may be a resonant panel loudspeaker, and the vibration exciter may excite resonant bending waves in the resonant panel.

The means resiliently locating the exciter on the support may comprise a resiliently flexible member connecting the exciter and the support. The support may comprise a structure on which the radiator is resiliently suspended. The structure may comprise a frame surrounding the radiator. A resilient suspension means may be provided and by which the radiator is suspended on the structure. The resilient suspension may be connected to the radiator at positions near to the edge of the radiator.

The means resiliently locating the exciter with reference to the support may be arranged to allow free motion of the exciter in an intended axial direction and to prevent motion of the exciter orthogonally of the axis. Where the radiator is a flat plate-like member, the axis may be orthogonal to the plane of the radiator.

From another aspect the present invention provides a

loudspeaker drive unit comprising a resonant acoustic radiator, a support body for the acoustic radiator, at least one vibration exciter on the radiator to apply bending waves to the radiator to cause it to resonate to produce an acoustic output, and means on the body suspending the exciter for free axial movement relative thereto so that the exciter is wholly mounted on the acoustic radiator in as far as concerns its axial operating motion to launch bending waves into the radiator. Thus the exciter is suspended on the body so that it is fixed against radial movement, that is to say movement in the plane of the radiator. The means suspending the exciter on the body may function in much the same way as the spider in a conventional pistonic loudspeaker drive unit. Thus the suspension means may be plate-like and may be formed with a series of circumferential and radial slits forming arms, the free ends of which form an outer part of the plate which can be fixed to the body while an inner part of the plate can be fixed to the transducer for the intended axial movement, while the plate remains stiff in its plane to prevent radial movement. A heat sink may be fixed to the exciter to assist in cooling the transducer.

The support body may take the place of a chassis or basket in a conventional loudspeaker drive unit, although in the present invention the support body is usually not required to be of the same degree of weight and rigidity as is required with a conventional pistonic drive unit. The support body (hereinafter support or support frame) may be

a lightweight frame-like structure.

The support frame may be such as to enclose the radiator panel. The frame may be a tray-like member having a surrounding peripheral lip. The frame may be of light weight and may, for example, be a plastics moulding. The frame may be open, or may be perforate or may even instead for a closed structure.

Means may be provided for resiliently suspending the acoustic radiator on the frame. The frame may be formed with means whereby it can be supported in position to form a loudspeaker.

The invention is diagrammatically illustrated, by way of example, in the accompanying drawings, in which:-

Figures 1 and 2 show a prior art loudspeaker as discussed above;

Figure 3 is a schematic view of another prior art resonant panel loudspeaker mounted to a frame;

Figure 4 is a schematic view of an embodiment of resonant panel loudspeaker mounted to a support frame in a manner embodying the present invention;

Figures 5a,5b,5c show equivalent circuits (mobility analogy) for the resonant panel loudspeakers of Figures 1,3 and 4 respectively;

Figure 6 is a perspective view of a second embodiment of loudspeaker according to the present invention;

Figure 7 is a perspective cross-sectional view of a modular loudspeaker drive unit in accordance with the present invention;

Figure 8 is an exploded cross-sectional perspective view of the modular assembly of Figure 7;

Figure 9 is a perspective view showing the interior face of a basket or chassis for the modular assembly of Figure 7;

Figure 10 is a perspective view of a resonant acoustic radiator panel for the modular assembly of Figure 7;

Figure 11 is a second exploded perspective view of the modular assembly of Figure 7, taken from a side opposite to that shown in Figure 8;

Figure 12 is a plan view of a suspension member used in the embodiment of Figure 7, and

Figure 13 is a scrap cross-sectional side elevation through the modular loudspeaker drive unit of Figure 7, taken on the line X-X of Figure 12, and showing the exciter suspension.

Figure 4 illustrates (in diagrammatic form consistent with Figures 1 and 3) a resonant panel loudspeaker (40), embodying the present invention. The loudspeaker (40) has many features in common with the loudspeaker (32) of Figure 3, and thus such features share the same reference numerals. The loudspeaker (40) includes a resilient suspension member (42), e.g. of rubber, disposed between the frame (34) and magnet assembly (24,26) of the exciter (12) to couple the exciter to the frame and resilient suspension (44) disposed around the periphery of the resonant panel (14), between the panel (14) and the frame (34). The resonant panel preferably comprises a resonant

member in accordance with International patent application WO97/09842.

In Figures 5a,5b,5c, circuit equivalents (mobility analogy) are used to illustrate the difference between the resonant mode panel loudspeakers of Figures 1, 3 and 4 respectively. In the circuits, inductance represents compliance (i.e. suspension compliance), capacitance represents mass, and resistance represents the inverse of mechanical damping. Thus, in Figure 5a, which is analogous to the loudspeaker (10) of Figure 1, the following terms apply: $Comp_{susp}$ represents resilience between the magnet assembly (24,26) and the panel (14); M_{coil} represents mass of the coil; M_{mag} represents mass of the magnet; and Z_{mp} represents panel mechanical impedance at driving point.

In Figure 5b, which is analogous to the loudspeaker (32) of Figure 3, the following extra term applies; M_{frame} represents the mass of the frame. Comparing with Figure 5a, an additional capacitor is placed in parallel with that representing the mass of the magnet assembly M_{mag}. This has the effect of reducing the fundamental resonance frequency of the system, which in the circuit is the resonance between the two parallel capacitors M_{mag} and M_{frame} and the inductor labelled $Comp_{susp}$.

In Figure 5c, which is analogous to the loudspeaker 40 of Figure 4, the following extra terms apply: $Comp_{frame}$ represents resilience between the panel (14) and the frame (34); and $Comp_{mag}$ represents resilience between the frame (34) and the magnet assembly (24,26). Comparing with

Figure 5b, we now have a sixth-order system, not a simple second order system. (Damping elements in a parallel with each of $Comp_{frame}$ and $Comp_{mag}$ have been omitted for clarity). It is the added complexity of the system which gives the designer the freedom to "tune" the loudspeaker.

Figure 6 discloses a second embodiment of resonant panel loudspeaker (50) embodying a resonant panel member (14) generally as disclosed in International patent application WO97/09842 of New Transducers Limited.

The loudspeaker (50) comprises a base (52) supporting a generally vertical rectangular light frame (34) which surrounds an acoustic radiator in the form of a stiff lightweight resonant panel (14) which is resiliently suspended in the frame on resilient members, such as rubber-like suspension members, not shown.

An inertial vibration exciter (12) is mounted to the panel to apply bending waves to the panel to cause it to resonate and the exciter is resiliently coupled to the rectangular frame (34) by means of slender resiliently flexible arms (54) which extend between the rectangular frame and the exciter. The arms (54) may, for example, be moulded integrally with the frame (34). Thus the exciter is located and coupled to the frame against movement in the plane of the panel while being free at least to some extent for movement orthogonally to the panel for inertial movement to excite resonances in the panel.

Figures 7 to 13 illustrate a third embodiment of the present invention in the form of a flat generally

rectangular modular loudspeaker drive unit assembly (60) comprising a generally rectangular stiff lightweight resonant acoustic radiator panel (14), e.g. of the kind described in International patent application WO97/09842 mounted in a surrounding frame or basket (62) with a pair of vibration exciters (12) mounted on the panel (14) to launch bending waves into the panel (14) to cause it to resonate to provide an acoustic output.

The basket (62) is generally rectangular and snugly encloses the radiator panel (14). The basket has a flat perforate base (66) having a surrounding peripheral lip (68) terminated by outwardly projecting flanges (70) which define a surrounding outwardly facing conduit (64) in which services such as electrical input leads to the vibration exciters (12) can be located. The conduit (64) is thus in the form of a channel extending round the periphery of the basket (62). The basket (62) is lightweight and may, for example, be a plastics moulding.

The acoustic radiator (14) is movably suspended on the basket (62) e.g. by its edges in any convenient fashion, e.g. by means of pivoted links (72) hinged at one end to the basket (62) and at the other end to the radiator panel (14).

The pair of inertial electro dynamic vibration exciters (12) are resiliently coupled or suspended on the basket (62) such that their motion normal to the plane of the radiator (14) is substantially unimpeded and to prevent movement of the exciters in the plane of the radiator (14)

whereby centration of the relatively movable parts of the exciters is enhanced. This exciter suspension resembles, at least in function, the spider commonly found in the drive unit of a conventional pistonic drive unit, except of course that a conventional spider is provided to ensure centration of a voice coil relative to a chassis. In the present case the suspension is in the form of a disc-like plate (74) e.g. of springy metal having an inner portion (86) attached to the exciter and an outer portion (88) attached to the basket, the inner and outer portions being separated such that the one can move normally with respect to the other and so that relative movement in the plane of the disc-like plate is prevented. This is achieved by slitting the outer portion (88) of the disc (74) with circumferential and radial slits (76,78) respectively to form three equally circumferentially displaced curved limbs (80) the free ends (82) of which are adapted to be attached to the chassis which the inner ends (84) of the limbs are attached to the inner portion (86). For this purpose the base (66) of the basket (62) is formed with a plate-like exciter locating portion (90) formed with opposed apertures (92) which align with and surround the respective exciters (12) and to which portion (90), the free ends (82) of the limbs (80) are attached. As shown in Figure 11, the portion (90) may be formed with upstanding pegs (98) adapted to engage in corresponding apertures (100) in the free ends of the links (80). Thus the suspension plates can be firmly fixed to the basket by forming the free ends

of the pegs (98) into rivet heads (102). A heat sink (94) is attached to each exciter (12) over the top of the suspension plate (74), to assist in cooling the exciters during use and the assembly is held together by a screw (96) sandwiching the upper part (86) of the suspension plate (74) between the exciter and the heat sink.

CLAIMS

1. A loudspeaker drive unit comprising a resonant acoustic radiator, an exciter on the radiator to apply bending wave energy to the radiator to cause it to resonate, a support for the loudspeaker drive unit, and means resiliently coupling the exciter to the support.

2. A loudspeaker drive unit according to claim 1, wherein the coupling means comprises a resiliently flexible member connecting the exciter and the support.

3. A loudspeaker drive unit according to claim 1 or claim 2, wherein the support comprises a structure on which the radiator is suspended.

4. A loudspeaker drive unit according to claim 3, wherein the structure comprises a frame surrounding the radiator.

5. A loudspeaker drive unit according to claim 3 or claim 4, comprising resilient suspension means by which the radiator is suspended on the structure.

6. A loudspeaker drive unit according to claim 5, wherein the resilient suspension is connected to the radiator at positions near to the edge of the radiator.

7. A loudspeaker drive unit according to any preceding claim, wherein the coupling means is arranged to allow free motion of the exciter in an intended axial direction and to prevent motion of the exciter orthogonally of the axis.

8. A loudspeaker drive unit according to any preceding claim, wherein the coupling means comprises a resilient plate-like member.

9. A loudspeaker drive unit according to any preceding

claim, wherein the exciter suspension comprises a plate having radially inner and outer parts, the outer part being formed by at least one opposed pair of arms having free ends, one of the group consisting of the inner and outer parts being adapted for attachment to the support and the other of the parts being adapted for attachment to the exciter.

10. A loudspeaker drive unit according to claim 9, wherein the plate is formed with a series of circumferential and radial slits defining the arms whereby an outer part of the plate can be fixed to the support and an inner part of the plate can be fixed to the exciter.

11. A loudspeaker drive unit according to claim 10, comprising a heat sink fixed to the inner part of the plate to assist in cooling the exciter.

12. A loudspeaker drive unit according to any preceding claim, wherein the support surrounds the radiator.

13. A loudspeaker drive unit according to claim 12, wherein the support is a tray-like member having a surrounding peripheral lip.

14. A loudspeaker drive unit according to claim 13, wherein the tray-like member is perforate.

15. A loudspeaker drive unit according to any preceding claim, wherein the radiator comprises a substantially flat panel.

16. A loudspeaker drive unit according to any preceding claim, wherein the resonant member is a member having capability to sustain and propagate input vibrational

energy by bending waves in at least one operative area extending transversely of thickness to have resonant mode vibration components distributed over said at least one area and have predetermined preferential locations or sites within said area for transducers means and having an exciter mounted on said member at one of said locations or sites to vibrate the member to cause it to resonate forming an acoustic radiator which provides an acoustic output when resonating.

17. A loudspeaker drive unit substantially as hereinbefore described with reference to, and as illustrated in, the accompanying drawings.

18. A loudspeaker comprising a drive unit as claimed in any preceding claim.

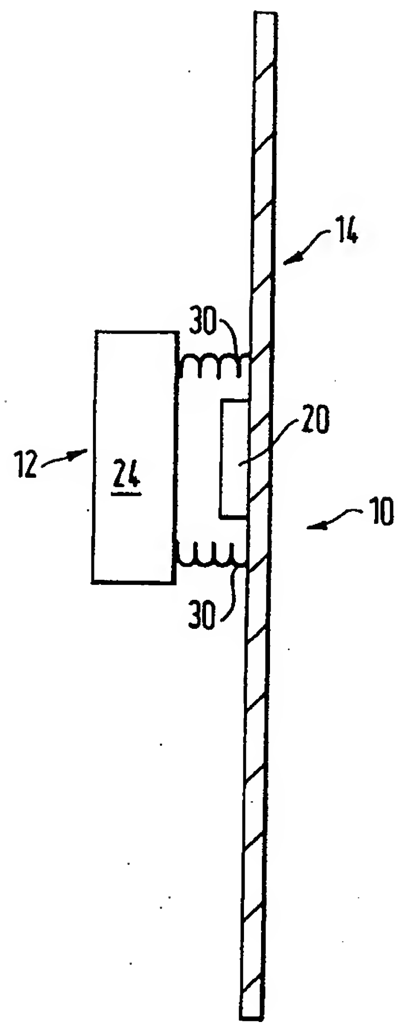


FIG. 1
PRIOR ART

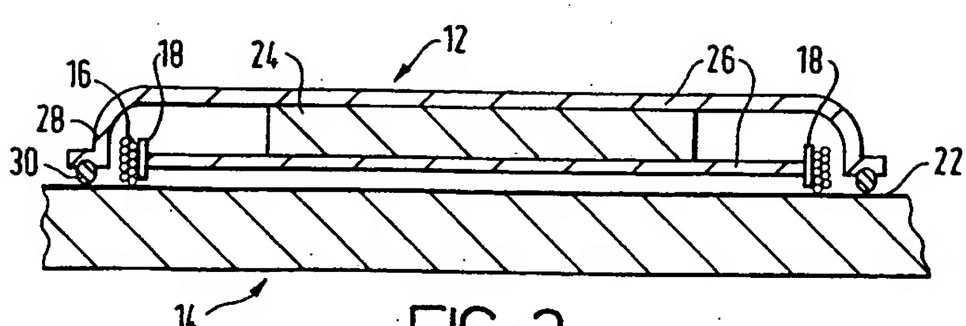


FIG. 2
PRIOR ART

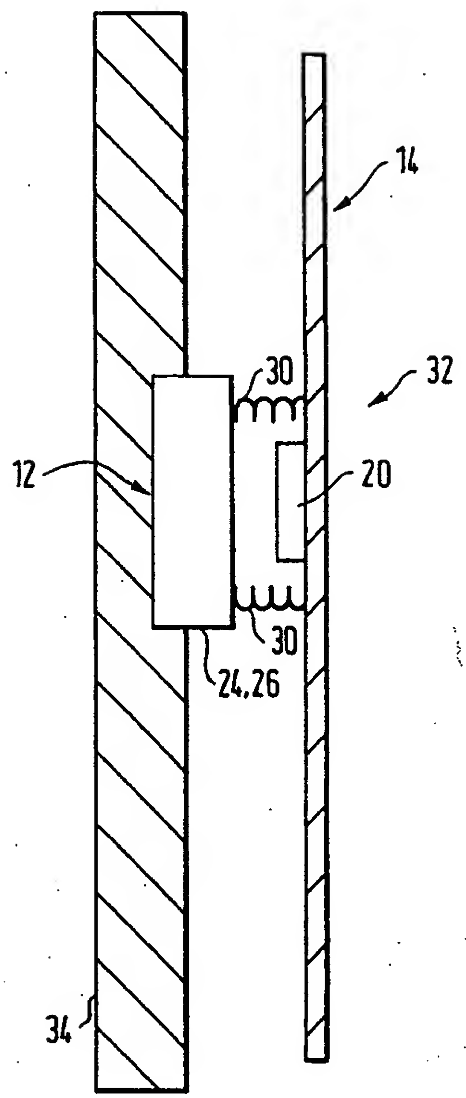


FIG. 3
PRIOR ART

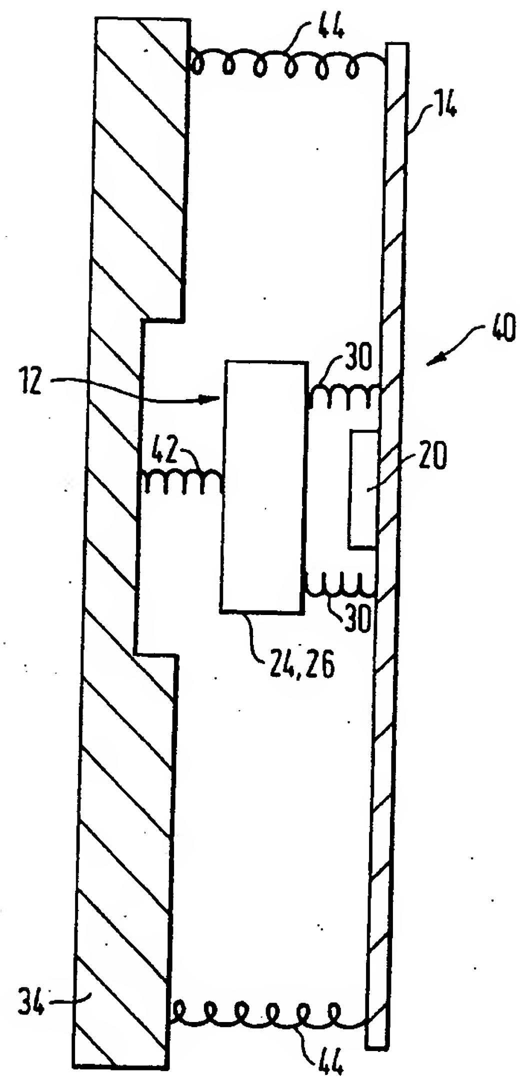


FIG. 4

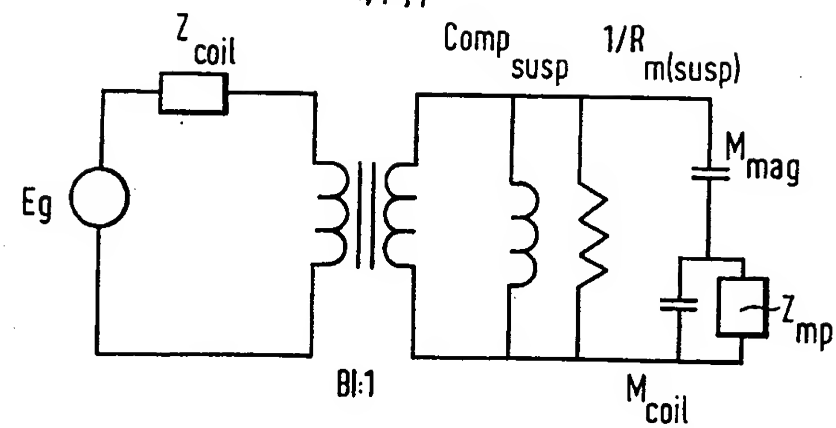


FIG. 5a
PRIOR ART

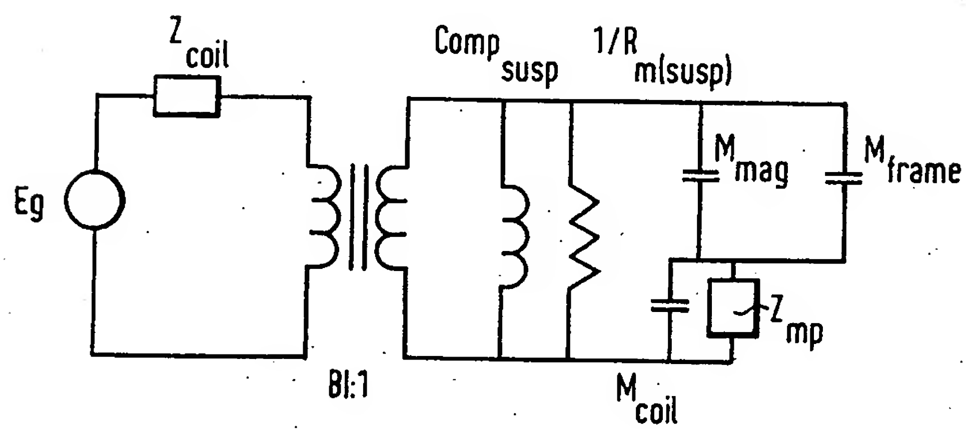


FIG. 5b
PRIOR ART

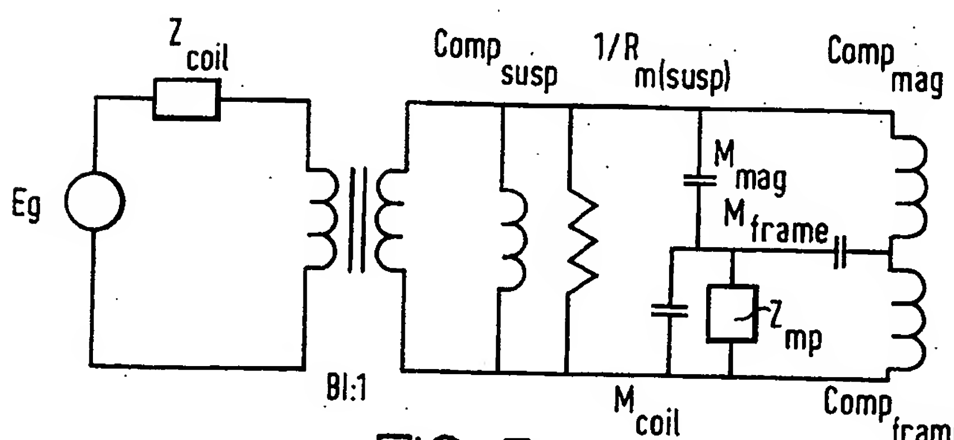


FIG. 5c

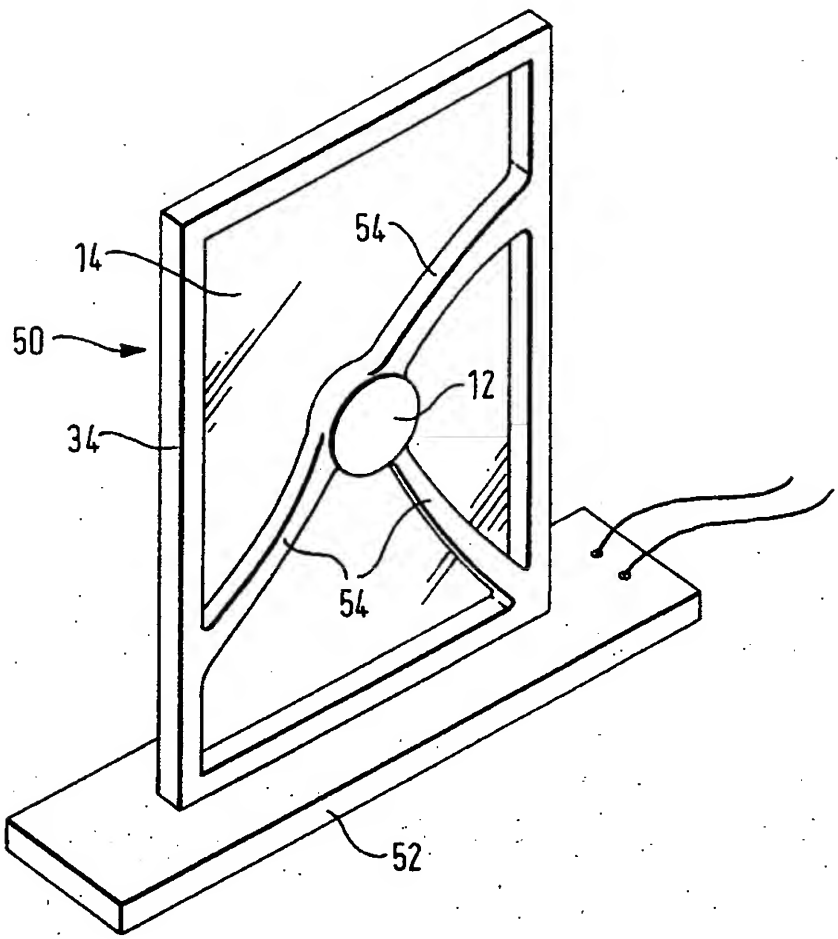


FIG. 6

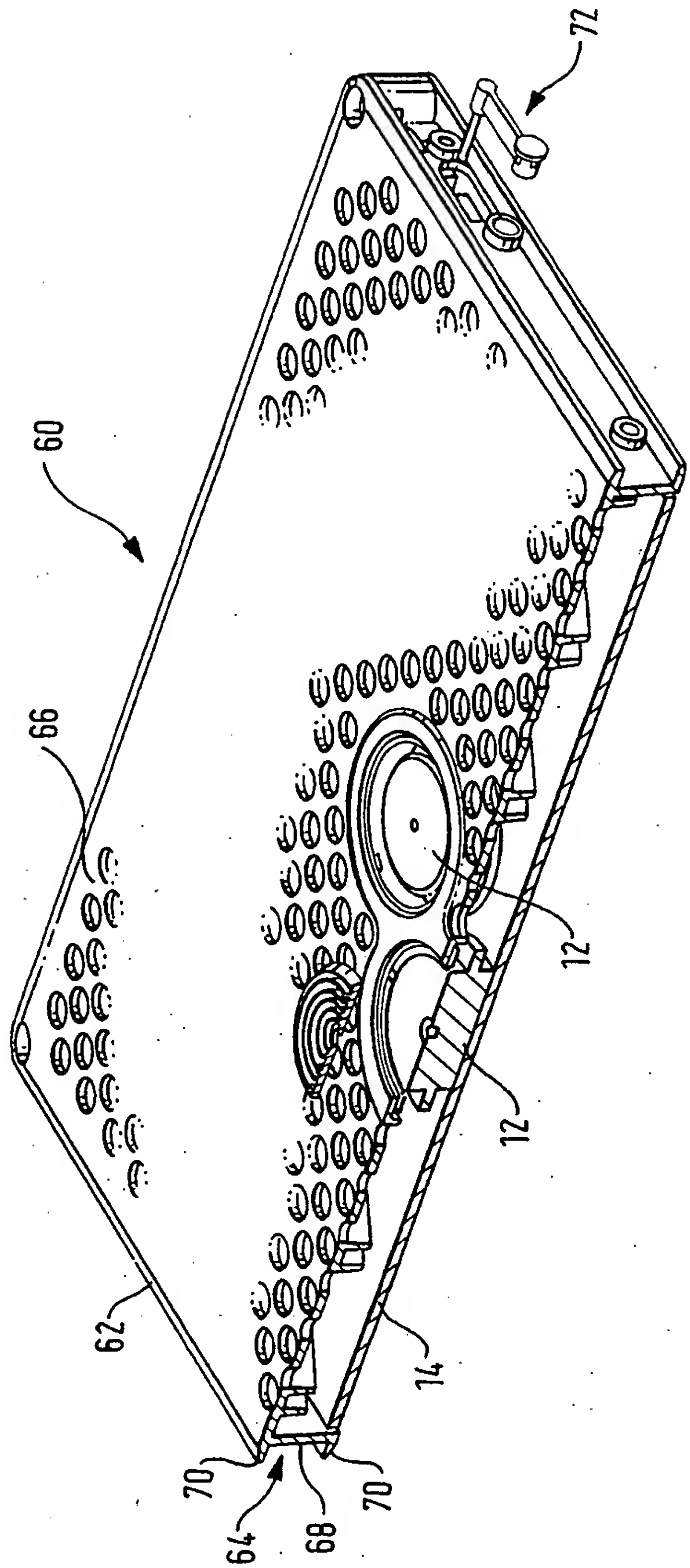


FIG. 7

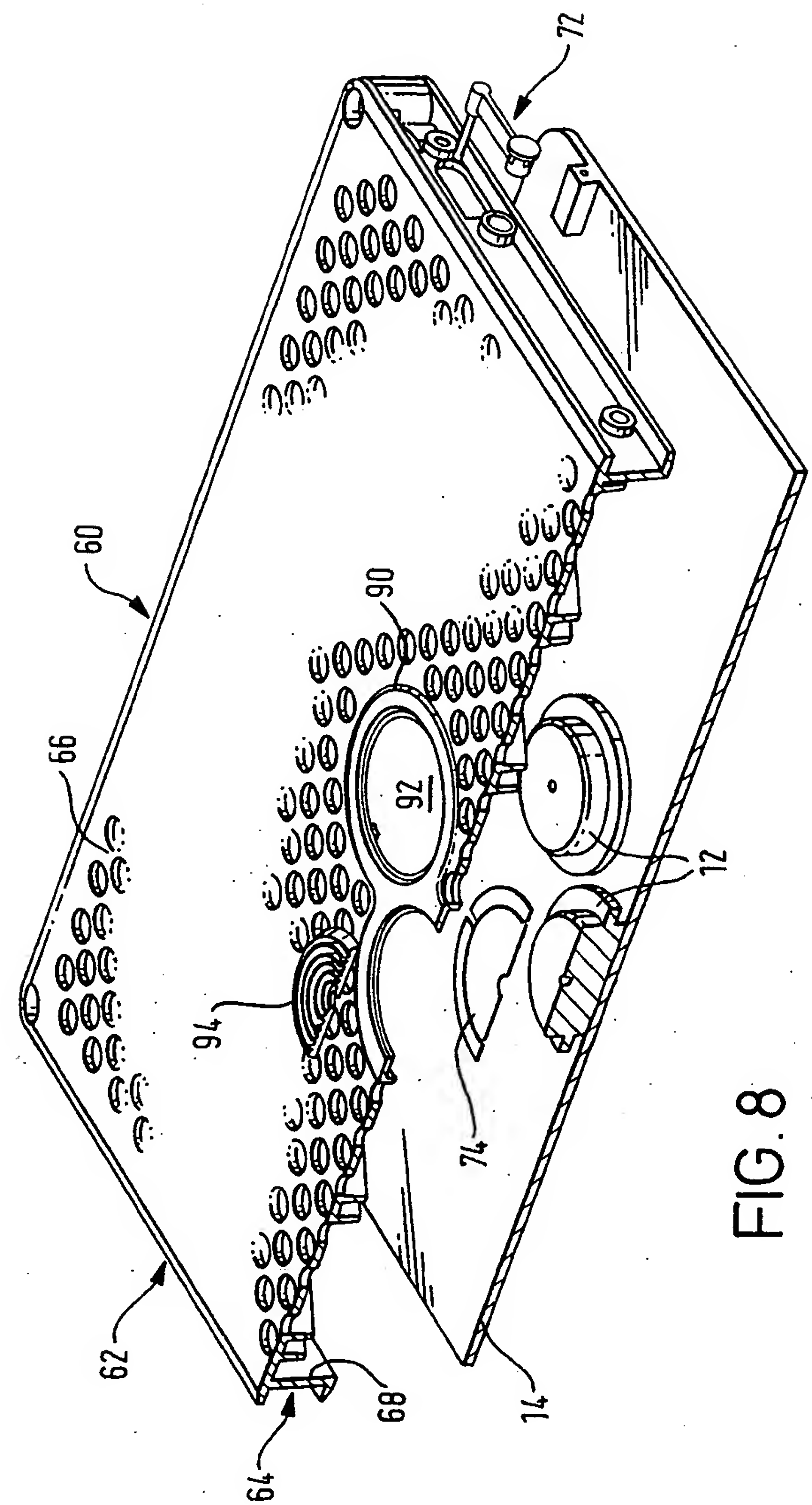


FIG. 8

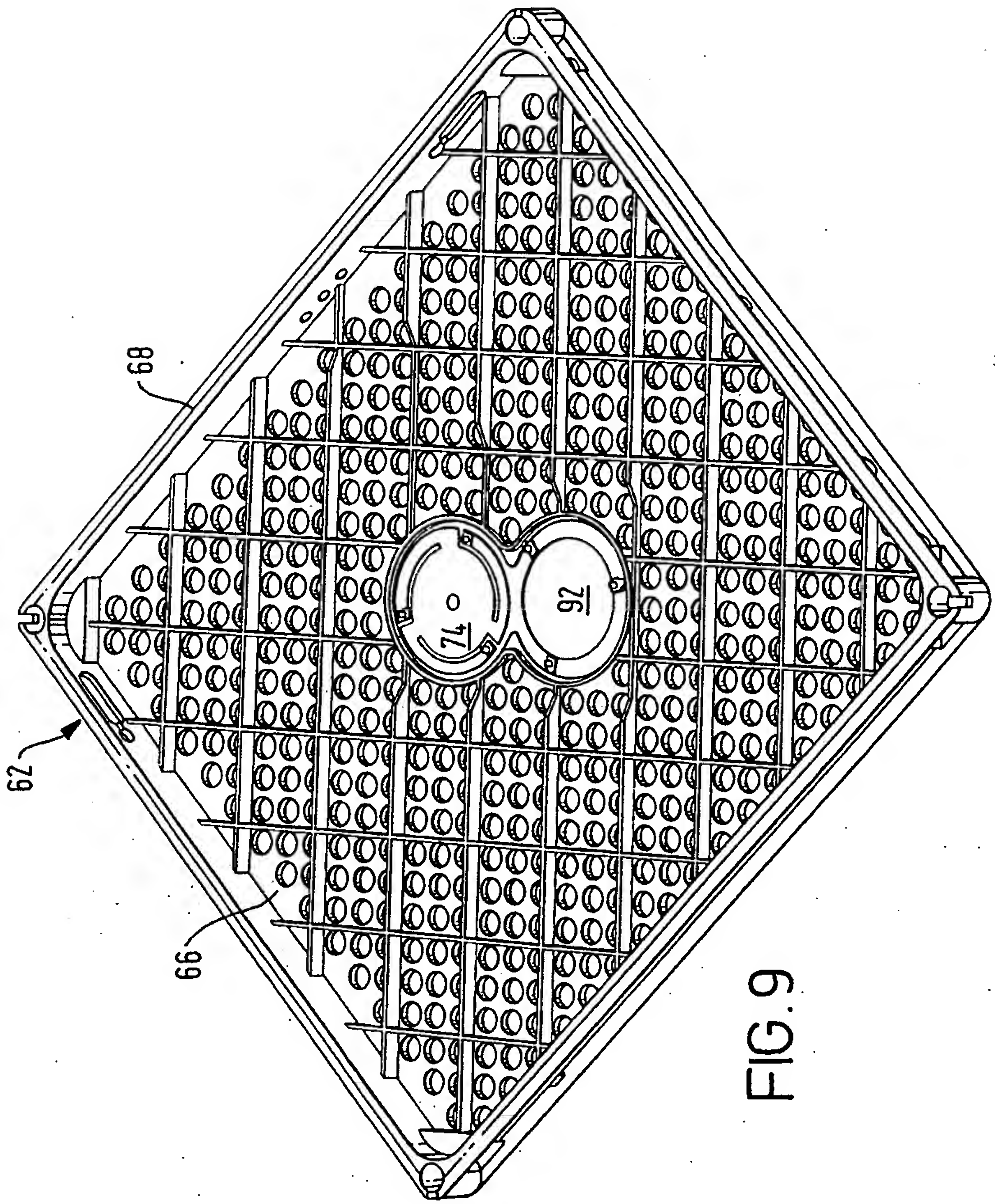


FIG.9

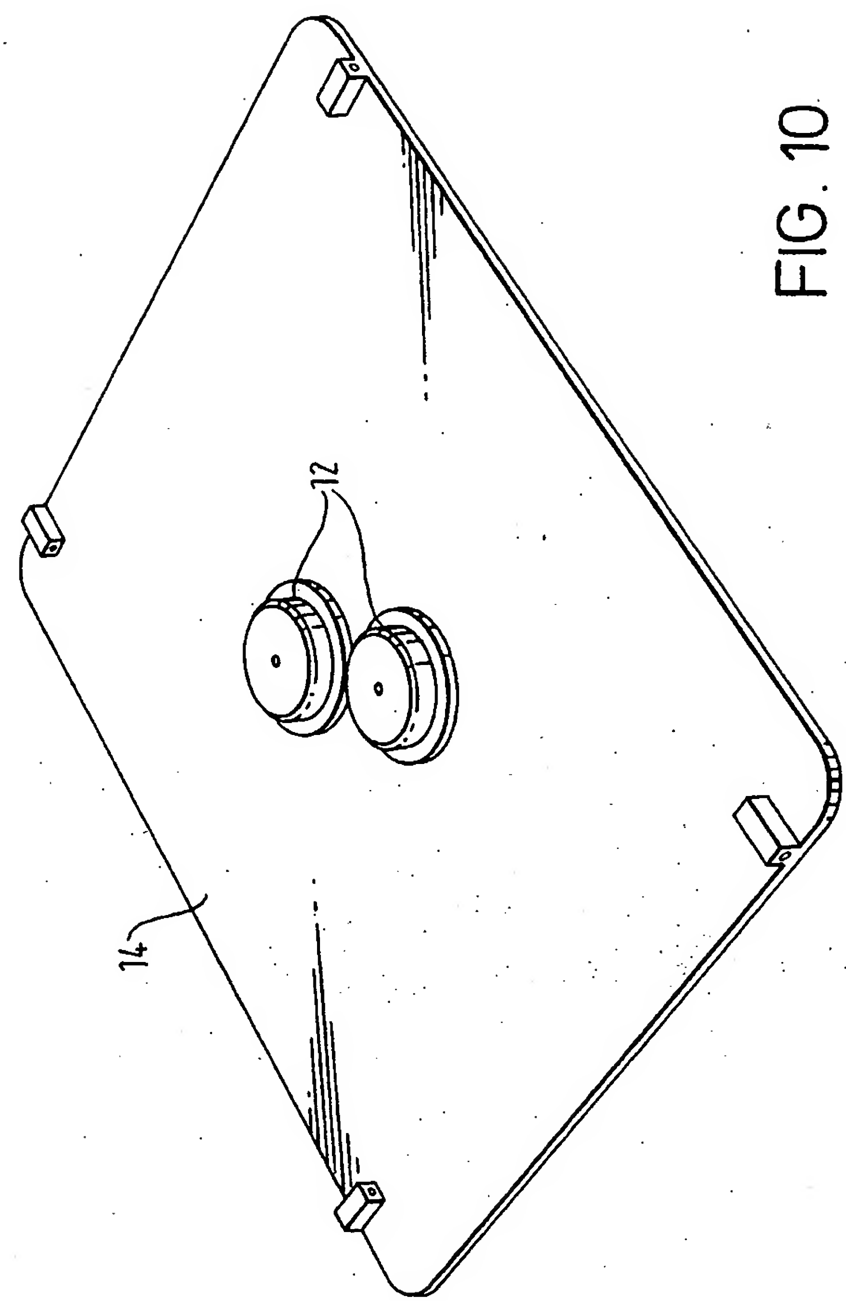


FIG. 10

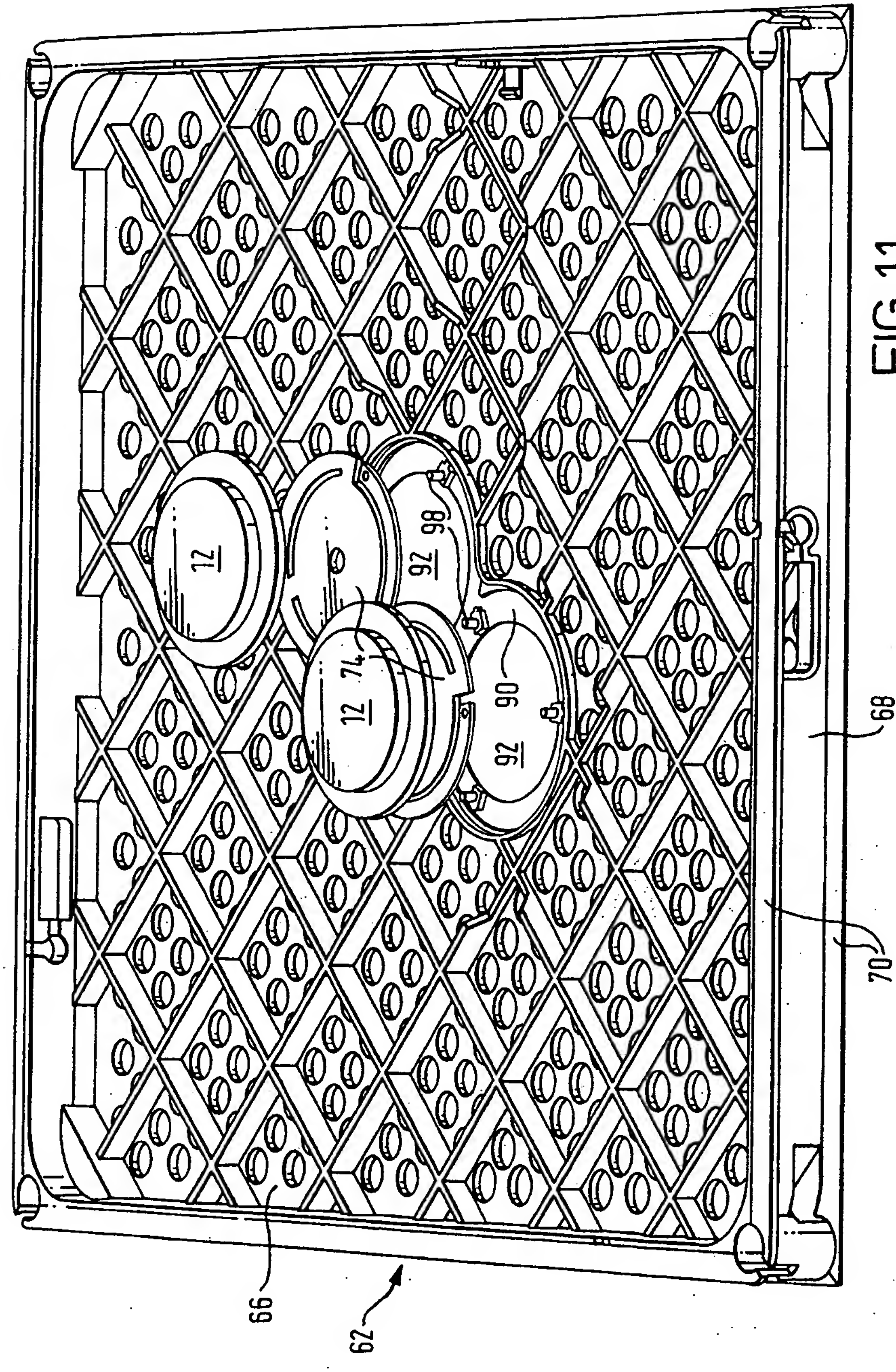


FIG.11

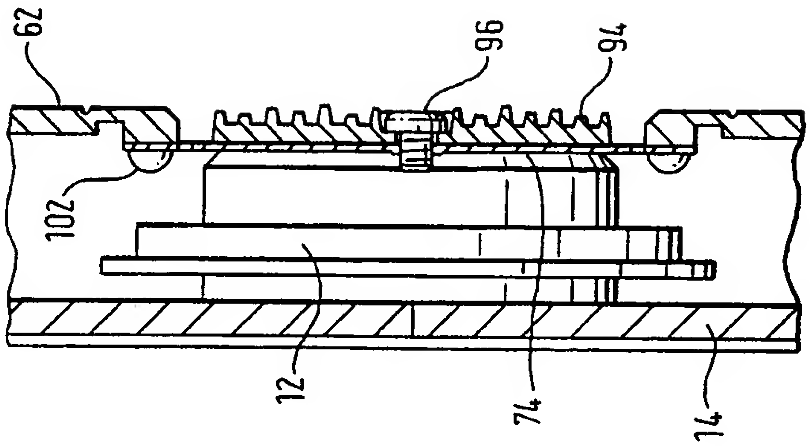


FIG. 13

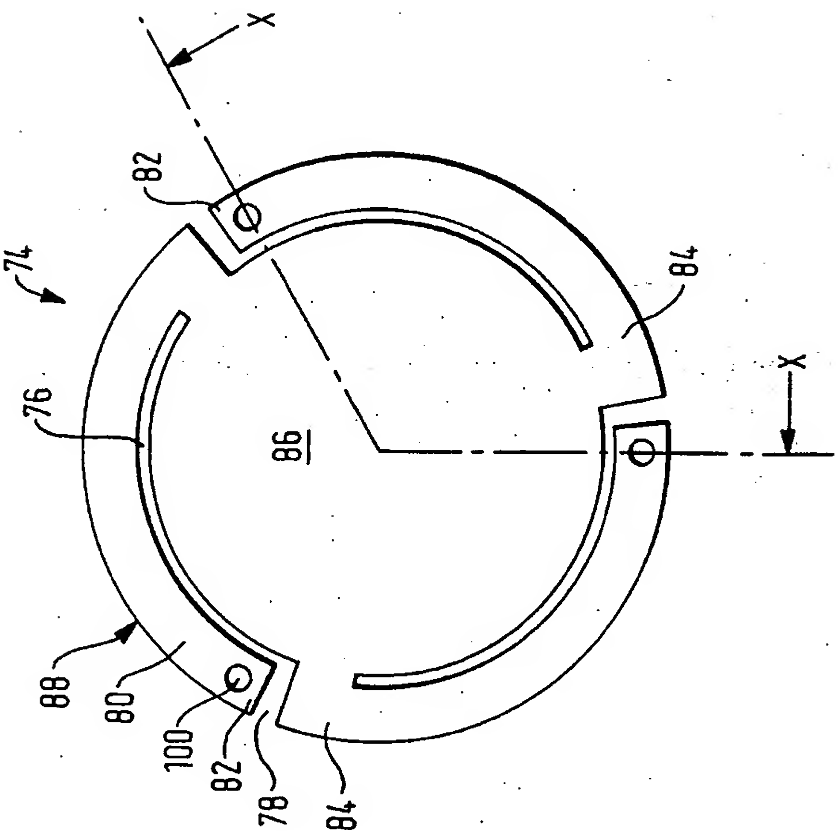


FIG.12